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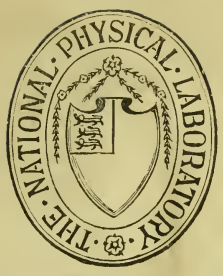

THE

NATIONAL PHYSICAL LABORATORY.

REPORT FOR THE YEAR 1904.

LONDON:
HARRISON AND SONS, ST. MARTIN'S LANE,
Printers in Ordinary to His Majesty.

1905.

THE NATIONAL PHYSICAL LABORATORY.

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REMOTE STORAGE

THE NATIONAL PHYSICAL LABORATORY.

REPORT FOR THE YEAR 1904.

Report of the Executive Committee.
Statement of Work for the year 1904.
Report of the Director, including—

(1) Report to the Director by the Superintendent of the Engineering Department.

(2) Report to the Director by the Superintendent of the Observatory Department.

REPORT OF THE EXECUTIVE COMMITTEE FROM JANUARY 1, 1904, TO DECEMBER 31, 1904, APPROVED BY THE GENERAL BOARD AT THEIR MEETING ON MARCH 17, 1905.

Work has continued on the various researches of a public character described in the Report for 1903.

In the Engineering Department the investigation into the distribution of wind pressure on large areas has been advanced considerably. A tower 50 feet in height has been erected on which to mount the plates under examination, and both the distribution of pressure and the total pressure on two similar rectangular plates—the one 10 feet by 5 feet, the other of one-tenth the area—have been investigated. The experiments are still in progress; further details are given in the Director's Report.

The machine for testing materials under alternating stress is at work; a description of it has recently been published (*Engineering*, February 17, 1905). Some results obtained by its use are described in the nickel-steel research referred to below, and progress has been made in the examination by means of photo-micrography of the method by which fracture takes place.

The advance made in the important research into the specific heat of super-heated steam is also described in the Director's Report. A number of results have been

obtained, but there are difficulties connected chiefly with the insulation of the heating coil which cause some uncertainty, and which have yet to be overcome before final figures can be given.

In the Metallurgical Division, the paper by Dr. Carpenter and Mr. Keeling on the Range of Solidification and Critical Ranges of Iron Carbon Alloys was finished, and read before the Iron and Steel Institute in May. The value of Dr. Carpenter's work was recognized by his election as a Carnegie Scholar. Thanks to the action of the Institute of Mechanical Engineers, which decided to continue at the Laboratory the work of their Alloys Research Committee, and voted a sum of £200 for the purpose, the Metallurgical staff was strengthened in April by the appointment of Mr. Longmuir, a pupil of Prof. Arnold, of Sheffield, and the nickel-steel research described in the Report for last year has been carried out by Dr. Carpenter and Mr. Longmuir, working jointly with Mr. R. A. Hadfield, to whose valuable co-operation the Committee are greatly indebted. The paper containing the results of the investigation is to be presented shortly to the Institution of Mechanical Engineers.

Dr. Carpenter, as Carnegie Scholar, has practically completed an important research on tool steels, utilizing to a great extent the steels provided by Mr. Matthews, and referred to in the Statement of Work for 1904.

The results of Mr. Smith's careful investigation into the mercury standard of resistance were communicated to the Royal Society in March last, and have since been published in the "Phil. Trans." for 1904.

Early in the year the Committee undertook for the B.A. Committee on Electrical Standards the completion of the standard ampère balance, designed by Prof. Ayrton and the late Principal Viriamu Jones. This has been carried through under Mr. Smith's care, and the balance is now practically ready for Prof. Ayrton's experiments.

Dr. Harker's research on the measurement of high temperatures has appeared in the "Phil. Trans." During the year he has been mainly employed in improving the means of making high temperature measurements and in extending the range of temperatures satisfactorily dealt with. Other slighter researches, now practically ready for publication, have dealt with the specific heat of iron up to 1,200° C., the melting-point of platinum, and the means of obtaining satisfactory materials for high temperature thermo-electric measurements. This last enquiry has gone on in conjunction with Messrs. Johnson and Matthey.

The first volume of the collected researches of the Laboratory, containing the papers referred to above and some important investigations on terrestrial magnetism, by Dr. Chree, is now ready for issue.

The equipment of the Laboratory has been extended during the year in various directions, and the Committee gratefully acknowledge the assistance they have received from various donors, whose names are given below. The more important pieces of apparatus and machinery thus acquired include a photographic lens testing bench, two optical benches for telescope and binocular glass testing work, a heavy lathe adapted for tests on high-speed steel, and a milling machine.

The Lathe House, containing the new standard leading screw machine, is completed, and the machine is at work. The first screw was cut for Messrs. Armstrong, Whitworth, & Co., the makers of the machine. The errors in pitch of this screw, measured from one end, lie between — 0·0003 and + 0·0002 inch in a length of 3 feet. The error of the standard leading screw itself at any point is only just in excess of 0·0001 inch.

The work of testing instruments and apparatus has increased. The total number of tests during the year made at Bushy House has risen from 1,330 to 2,006, while the fees for tests have grown from £350 8*s.* 4*d.* to £975 19*s.* 8*d.*, an increase of £625 11*s.* 4*d.*, and, in addition, £1,497 19*s.* 1*d.* has been received for special enquiries and researches.

The following table gives details for the past three years :—

COMPARISON OF TESTS MADE DURING THE YEARS 1902, 1903, 1904.

Physics Department.

Electricity and Magnetism.

	1902 (9 months).	1903.	1904.
Resistance Coils	—	128	131
Resistance Boxes and Testing Sets	—	4	152
Condensers	—	11	2
Conductivity Tests	—	7	34
Permeability and Hysteresis Tests	—	8	9
Inductance Tests	—	3	2
Ammeters	—	—	12
Voltmeters	—	—	32
Supply Meters	—	10	4
Wattmeter	—	—	1
Ohmmeters	—	—	2
Permanent Magnets	—	10	—
Potentiometers	—	—	16
Standard Cells	—	—	11
Secondary Cell	—	—	1
Callendar Recorders	—	—	2
Insulation and Dielectric Strength	—	—	4
Miscellaneous	—	14	—
	— 31	—195	—415

Thermometry.

High Range Thermometers	—	59	77
Low Range Thermometers	—	—	4
Open Scale Thermometers	—	9	10
Platinum Resistance Thermometer	—	—	1
Melting Point of Alloys	—	13	—
Freezing Point of Liquids	—	5	—
Thermocouples	—	—	3
Callendar Griffiths' Bridges	—	—	3
Callendar Recorders	—	—	2
Miscellaneous	—	7	41
	— 39	— 93	—141

*Metrology.**

	1902 (9 months).	1903.	1904.
Micrometer	—	1	1
Coefficients of Expansion	—	9	11
Deflection Bars	—	4	9
Inertia Bars	—	5	17
Gauges	—	23	119
Scales	—	1	9
Density Determinations	—	28	—
	— 12	— 71	—166

Testing of Glass Vessels and Weights.

Glass Vessels, Burettes, Flasks, &c.	—	665	365
Chemical Weights	—	49	75
	—116	—714	—440

Metallography.

Photomicrographs of Specimens of Metals...	—	57	84
Cooling and Heating Curves	—	14	14
	— 16	— 71	— 98

Chemical Tests.

Complete Analyses	— 10	— 47	— 22

Microscopical Tests.

Slides of Water Deposit	—	—	3
Samples of Paper	—	—	—
	— 5	— 0	— 3

Optics.

Pentane Lamps	—	—	8
Incandescence Lamps	—	14	447
Gas Mantles, &c.	—	—	34
Photographic Lenses	—	8	6
Optical Constants	—	—	2
Sunshine Spheres	—	3	—
	— 0	— 25	—497
	229	1,216	1,782

* A large number of miscellaneous tests of working parts and components have been made for the Engineering Standards Committee.

ENGINEERING DEPARTMENT.

	1902 (9 months).	1903.	1904.
Gauges (Vacuum and Pressure)	—	19	24
Strength of Materials	—	83	80
Steam Pipe Lagging	—	4	3
Calorific Value of Fuel	—	3	13
Air Meter Tests	—	1	4
Sets of Rubber Tests	—	4	—
	40	114	124

It is clear from the above table that the increase in the number of instruments tested has taken place in almost all the divisions of the Laboratory. Reference is made to the more important tests in the Report of the Director. Among these may be specified the series undertaken for the English Exhibition at St. Louis, a large proportion of the electrical apparatus sent out being examined at the Laboratory.

A large number of electrical and photometrical tests have also been made for the Admiralty on resistance boxes, ammeters, voltmeters, lamps, and other apparatus. Tests of gas mantles have been undertaken for the Office of Works.

In the Department of Metrology the number of gauges, etc., examined continues to increase. Much of this work has been done for the Engineering Standards Committee, while the examination of scales and gauges required by the Standard Leading Screw Committee of the War Office has occupied a considerable amount of time.

The only division in which a serious fall in numbers is shown is that concerned with the testing of glass vessels, etc. This is due to the fact that special terms were offered to the makers to lay in a stock of tested vessels in 1903; this stock has not been used up.

At the same time a number of tests have been declined for want of equipment, among these may be mentioned strength tests on boiler plates, steel bolts, cement, &c., for the Board of Trade, the London County Council, Colonial Governments, and various public bodies and private firms.

As part of the remunerative work of the Laboratory, in addition to the tests, the Committee would call attention to a number of researches for firms or public bodies which have been in progress.

Early in the year the Committee were asked to undertake an investigation into a number of samples of guttapercha submitted for a complete mechanical electrical and chemical examination. A long series of tests, comprising measurements of resistance, inductive capacity, dielectric strength, tensile strength, and other properties, together with a careful chemical investigation of the samples has been made, and an elaborate report sent in. The Director has been informed by the representative of the firm that the work will be very valuable to them. Arrangements are now under consideration for its extension.

A similar piece of work has been a photometric enquiry into a large series of electric lamps of various patterns made for a government department, with a view, principally, to determining whether the over-running test, which is now frequently employed, and

the ordinary life test really give comparable results, and to draw up a satisfactory specification. With regard to this series of tests, the Committee are glad to acknowledge the assistance which the Director reports he received, both during his visit to America and since his return, from the Lamp Testing Bureau of New York.

Two series of investigations have been made for the Motors, Generators, and Transformers Sub-committee of the Engineering Standards Committee. One of these was an enquiry into the effect of temperature on the dielectric strength and other properties of insulating materials used in the construction of electric machinery. This has been presented to the Sub-committee, and is acknowledged to be of great value. The second enquiry, carried out with the cordial assistance of a number of dynamo builders, has been an investigation into the distribution of temperature in the field coils of dynamos, motors, etc. The report is now before the Committee.* The two researches have had the same object, viz.: to enable the Committee to specify the limits of temperature permissible in various kinds of machinery and the methods of measuring the temperature. A similar investigation into the distribution of temperature in transformers is now in progress.

In accordance with the arrangement with the India Office the volume of tidal predictions for India for 1905 was issued by the Laboratory. The volume for 1906 is well in hand.

Turning now to the Observatory Department, the Committee have to report that the work of testing apparatus continues; a number of details will be found in the Superintendent's Report. They regret, however, to record a large decrease in the total number of instruments tested. This total is dominated by the clinical thermometers, which have decreased from 19,393 to 15,903. The Committee are inquiring into some of the causes of this drop. A table giving the numbers tested follows:—

COMPARISON OF NUMBERS OF INSTRUMENTS VERIFIED DURING THE YEARS 1902, 1903, 1904.

OBSERVATORY DEPARTMENT.

	1902.	1903.	1904.
Absolute Magnetic Instruments	26	13	13
Mercury Barometers	271	305	267
Aneroid Barometers	122	79	170
Hydrometers	410	363	777
Clinical Thermometers	22,856	19,393	15,903
Other Thermometers	3,086	3,240	3,454
Compasses	16	9	29
Sextants	769	901	957
Telescopes	1,678	3,180	2,943
Binoculars	924	1,048	1,027
Lenses	12	To Bushy	To Bushy
Watches	520	447	434
Chronometers	39	60	36
Milk Test	159	89	131
Miscellaneous	187	360	136
	31,075	29,487	26,277

* Since this Report was approved by the Executive Committee, the Engineering Standards Committee have published these Reports.

The English Antarctic Expedition returned in September, and various meteorological and physical instruments employed by the Expedition have been sent to the Laboratory for re-verification. The Committee have also undertaken to co-operate in the reduction of the magnetic, geodetic, and some other observations.

The officials in Scotland of the Office of Works report progress with the building of the Observatory at Eskdale Muir; a fair amount of preliminary labour has been got through, and the Committee trust the main work of erecting the buildings will be completed this year.

The income received from the Gassiot Trust has been expended in furtherance of the objects specified in the Gassiot Trust Deed of 1871.

During the summer the Director visited America as a representative at the Electrical Congress at St. Louis of the Institute of Electrical Engineers. He was also appointed to act as a Delegate from the English Government and from the Royal Society.

The Congress passed two resolutions, the one in favour of a formal International Conference to deal with outstanding questions connected with electrical units; the other in favour of co-operation among the leading Technical Societies of the world to secure standardization of electrical machinery. The Committee realize the importance of both these objects, and are glad to learn that the English Government are willing to nominate delegates to a Conference dealing with fundamental units.

The financial position during the earlier part of the year was a cause of some anxiety to the Committee; the large additions made to the donation fund, which has risen from £1,124 3*s.* 0*d.* to £2,313 13*s.* 0*d.*, and the increase in the work during the latter part of the year have, however, turned the loss which was feared into a balance. The expenditure during the year has been £12,257 3*s.* 7*d.* and the receipts £12,753 3*s.* 9*d.*, showing a balance in favour of the Committee, on the year's working, of £496 0*s.* 2*d.* While this result is satisfactory, the Committee realize it is due in great measure to the efforts made by the Special Fund Committee to increase the donation list, and that such a source of income is necessarily a precarious one. In addition, a sum of £1,315 18*s.* 2*d.* has been spent on equipment, mainly out of previous accumulations of income. The balance is now £4,142 0*s.* 4*d.*, as against £2,379 9*s.* 11*d.* at the beginning of the year, but this includes a donation of £2,000 and £395, the balance of a donation of £500, made recently for new equipment.

The sources of income have been as under, and may be compared with the receipts in 1903:—

	1903.			1904.		
	£	*s.*	*d.*	£	*s.*	*d.*
Government Grant	4,000	0	0	4,000	0	0
Gassiot Fund	426	12	2	453	14	4
Donations and Subscriptions	1,124	3	0	2,313	13	0
Charges for Work done	4,347	9	5	5,625	16	0
„ for Commissions for Foreign and Colonial Governments	255	2	6	318	1	8
Miscellaneous Receipts	46	17	2	41	18	9
	£10,200	4	3	£12,753	3	9

Fuller particulars as to these receipts, and details of the expenditure, are given in the printed statement of accounts.

In estimating the receipts for work done it must be remembered that a large proportion of the donations and subscriptions come from technical and learned societies which expect contributions in return in the form of research work of importance to their members. In some cases the actual research to be carried out is specified. Thus some large part of the subscriptions is really payment for work.

In the Report for 1903 some account was given of the preliminary steps taken to bring the needs of the Laboratory before the Government, in view of the fact that the five years for which the grant of £4,000 was made lapsed in September, 1904. In accordance with a request from the Treasury, the Committee prepared for the Royal Society a detailed scheme for carrying on the work. This was submitted to the Government and discussed at a meeting in the Chancellor of the Exchequer's room in July last.

A reply has been received from the Lords Commissioners of His Majesty's Treasury, in which their Lordships express their readiness to place on the Estimates an increased grant to provide for an augmentation in the number and salaries of the staff. The annual grant for 1905–6 is to be £5,500, an increase of £1,500, and their Lordships will, in addition, be willing to consider whether this sum of £5,500 should, in the Estimates for 1906–7, be further increased by a sum not exceeding £500 a year, making a total of £6,000.

The memorandum of the Committee also pointed out the need for capital expenditure on new buildings and equipment of a sum approaching £30,000.

With regard to this Their Lordships write :—

> "With every desire to develop in the public interest the resources of the National Physical Laboratory, My Lords feel that this somewhat extensive programme is one which, having regard to the financial exigencies of the time, and the numerous other demands on the Exchequer, can only be carried out by being spread over a number of years. They will, however, be prepared to ask Parliament for an additional grant of £5,000 for 1905–6, and they hope that for four or five years to come it may be possible to provide an equal amount."

In reply to a request from the Royal Society for an expression of their opinion, the Executive Committee have asked the President and Council to convey to their Lordships their thanks for the increased grants. They have felt, however, bound to observe that the sum of £6,000 per annum falls considerably short of the amount of £10,000 which, as they pointed out in their Memorandum, will, in their opinion, be ultimately necessary to discharge the duties which have been laid upon the Executive Committee, while the long period over which the work of equipping of the Laboratory is to be spread will make its full development slow. At the same time the Committee gratefully realize that the additional resources thus placed at their disposal will enable them at once to extend their work, and they cannot doubt that the public utility of the operations of the Laboratory will in future establish a claim for further assistance from His Majesty's Government.

Since the receipt of this reply the Committee have had under consideration the question which of the extensions described in the Memorandum is the most urgent and have decided to obtain plans and tenders for two new buildings to house the Departments of Electrotechnics and Metrology.

SUBSCRIPTIONS RECEIVED IN 1904 TOWARDS THE PROPOSED ANNUAL FUND OF £2,500.

Institution of Civil Engineers	£500	
Iron and Steel Institute	200	
Railway Companies' Association	200	
Sir W. G. Armstrong, Whitworth & Co.	200	
Society of Chemical Industry	100	
Manchester Steam Users' Association	100	
The India Rubber, Gutta Percha and Telegraph Works Co.	100	
Mr. R. Kaye Gray	100	
Mr. M. H. Gray	50	
Eastern Telegraph Co.	50	
Mr. C. Hawksley (£250, being total subscription for 5 years, received)	50	
Sir E. H. Carbutt, Bart.	25	
Sir Bernhard Samuelson, Bart.	25	
Sir Benjamin C. Browne (£100, being total subscription for 5 years, received)	20	
Consett Iron Co.	10	10*s.*
Messrs. Alex. Wright & Co.	3	3*s.*
The Clothworkers' Company	100	

The following Donations and Contributions have also been received, in addition to those previously mentioned :—

Anonymous	£2,000
Anonymous	500
Alloys Research Committee of the Institution of Mechanical Engineers	200
Manchester Steam Users' Association, towards cost of experiments on specific heat of superheated steam	150
Messrs. Ross, Ltd., towards cost of photographic lens-testing bench	100
Sir Andrew Noble, for Studentship	50
Messrs. R. & J. Beck, towards cost of photographic lens-testing bench	25

Sir Andrew Noble, Sodeau gas analysis apparatus.

Prof. H. S. Hele-Shaw, Patent Driving Clutch.

Messrs. Barr & Stroud, vacuum pump.

Sir Arthur Rücker, magnetic instruments used in the Magnetic Survey of the British Isles.

Prof. J. A. Fleming, three large bulb standard photometric lamps.

The Ediswan Company, standard lamps, Fleming pattern.

The Incandescent Electric Lamp Co., Robertson standard lamps.

Messrs. Alexander Wright & Co., Flicker photometer.

Messrs. Aitchison & Co., apparatus for testing binoculars.

Sir E. H. Carbutt, Bart., iron castings required for experimental work.

Messrs. Cammell, Laird & Co., an H-form bar for a 4-metre standard of length.

The Governments of New Zealand and of Western Australia have also each promised a donation of £100 towards the expense of establishing a comparator for long tapes.

STATEMENT OF WORK FOR THE YEAR 1905, APPROVED BY THE GENERAL BOARD AT THEIR MEETING ON MARCH 17, 1905.

ENGINEERING DEPARTMENT.

Wind Pressure Research.—It is proposed to complete the observations on the distribution of pressure on similar plates of the 50 square feet and 5 square feet area which have been partially surveyed. For the determination of the resultant pressures of all the plates a new form of pressure gauge has been designed and partially completed. The readings of this gauge will, it is hoped, be quite unaffected by the inertia of the plates, and will, consequently, afford a check on the measured distribution of pressure. It appears probable that experiments on plates of intermediate areas, and also of areas exceeding 50 square feet, will be necessary in order to form an estimate of the dimensional effect on the mean pressure. The experiments will then be extended to the cases of roof models and bridge models of as large an area as can be safely carried by the tower and framework.

Resistance of Materials under Alternating Stresses.—It is proposed to commence this research at once on the samples of steel and iron, which have been kindly given by Mr. Hadfield for the purpose. These materials are:—

(1) Swedish iron.
(2) Steel containing ·2 per cent. carbon.
(3) „ „ ·4 „ „
(4) „ „ ·6 „ „

In the first series of tests the rates of alternation will vary from 600 to 1,000 per minute. On the completion of these, a second crank shaft will be fitted to the machine of one quarter the throw of the present one, and with this trials will be made at rates of alternation varying from 1,000 to 2,000 per minute. In this way it is hoped to obtain the relation between the limiting range of stress and the rate of alternation, which has hitherto only been studied between rates of 1,300 and 2,400 per minute.

It is further proposed to study the effect of alternating stresses of comparatively large periods, *i.e.*, 2 or 3 per minute, on the same specimens as are used in the high speed testing machines. For this purpose a small one-ton single lever testing machine, provided with reversible knife edges, has been designed and is approaching completion in the workshop. With this machine it will be possible to produce gradual reversals of stress in the specimen without changing the gear of the machine or taking off the extensometer. By this means the range of the true elastic limits in tension and compression will be determined for the material, which is to be subjected to alternating stresses at high speeds.

Tests on Pressure Gauges.—It is proposed to carry out a series of tests on pressure gauges on the lines suggested by Mr. Stromeyer recently. Consultations have been held with some of the leading gauge manufacturers with regard to the nature and scope of the tests, and these having been agreed upon, the apparatus required is now being designed. The tests will include endurance, friction and backlash, heat and vibration tests. For the purpose of the vibration tests the gauges will be mounted on an elastic platform which can be subjected to a periodic disturbing force, whose period can be varied within fairly wide limits.

Steam Research.—Various modifications of the apparatus are to be tried in order to get over the difficulties described in the report on the work of 1904. When these points are settled the apparatus will require rebuilding in a more permanent fashion; access to a larger boiler would be desirable.

PHYSICS DEPARTMENT.

Electricity Division.

Fundamental Units.—The work suggested for the year 1905 comprises :—

(1) The completion of the electrical equipment of the Ampère Balance for the British Association.

(2) The completion of the investigation of certain anomalies of standard cells, with a view to the preparation of a satisfactory specification. The effects of acidity, of rapid changes of temperature, of short circuiting, and of rough usage, will, among other things, be investigated.

(3) An investigation of the methods adopted for evaluating a current by the deposition of silver. The Rayleigh and Richards form of voltameter will be compared, and the influence of temperature, current density, surrounding atmosphere and other possible disturbing features about which there exists considerable uncertainty, will be investigated.

(4) Possibly some preliminary experiments in order to decide on the best form of Lorenz apparatus to be presented by the Drapers' Company.

General Electrical Measurements.—In connection with the increasing number of ammeters and voltmeters coming in to be calibrated, an investigation is proceeding with a view to setting up standard moving-coil galvanometers quite free from zero creep. They are to be fitted with sets of shunts and added resistances, and, used in conjunction with a potentiometer for setting them, they will be used as standard ammeters and voltmeters for direct current.

As secondary standards to facilitate the testing of the magnetic permeability of iron in the form of short bars, a series of bars typical of the varieties of material likely to be met with in practice is being constructed.

The design of a portable instrument for measuring small stray magnetic fields is under consideration.

For inductance and capacity measurements the construction of a small high frequency alternator (for 10,000 revolutions per second) has been commenced. This will be proceeded with, and slide-wires and other auxiliary apparatus will also be made.

Magnetic Tests on Iron.—A research has been taken in hand on the effect of heat ageing on the magnetic hysteresis of sheet iron, with a view to obtain, if possible, a non-ageing material with low hysteresis loss. For this purpose a firm of leading manufacturers is preparing for us a large number of samples in the form of rings and strips. One set of these samples is to be of uniform chemical composition, but submitted to various courses of heat treatment. Another set is to be of varying chemical composition, all annealed similarly, while a third batch is to include typically inferior material. A large electrically-heated oven is ready, and in this the various samples will be submitted to steady temperatures. At intervals hysteresis tests will be made. After examination of the first set of results it is probable that some, if not all, of the samples

will be submitted to re-annealing (or other heat treatment), and after this the ageing tests repeated. It is hoped that in this way some clue will be obtained to the conditions which determine the magnetic quality of the material as regards ageing.

Experiments for the Engineering Standards Committee.—In response to a request from the Engineering Standards Committee, a series of tests on the distribution of temperature in transformers, similar to those already made on dynamos, is being undertaken with the co-operation of various prominent firms, which have constructed special transformers for the work. Thermo junctions of iron-eureka have been embedded in these, and will allow the temperature to be measured at various points. Determination of the efficiency of the transformers will also be made.

Electro-Technics.—The more complete equipment of a department for the rapid testing of commercial instruments, voltmeters, ammeters, &c., both for direct and alternate currents, is a pressing necessity, and the Committee hope that some considerable portion of the funds available for capital expenditure during the year may be thus utilised.

Thermometry Division.

The work in prospect for 1905 includes :—

(1) The completion of the enquiry now in progress as to the suitability of various thermometer glasses for high temperature work, and the continuation of the study of the properties of various glasses and the changes of zero of thermometers over extended periods of the various temperature cycles.

(2) The continuation of the research on the physical properties of steam. It is hoped to complete the investigation now in progress on the specific heat of superheated steam over moderature pressures and superheats.

(3) A general investigation into the methods of attaining and measuring very high temperatures, and in particular the elaboration of some form of electrical pyrometer for measurement of temperatures up to, say, 1,800° C. As it has been conclusively shown that no metals hitherto used in pyrometers will continue to withstand for any length of time the combined effect of the action on them of the furnace vapours and gases by which they are surrounded, and that of high temperatures such as 1,500° C., attention has been turned to the various oxides of the alkaline earths and allied groups with a view of elaborating from some mixture of these, such as is used in Nernst lamps, substances possessing sufficiently unalterable physical properties to enable them to be used as the basis of a system of high temperature measurement. As stated in the report of the Director for 1904, the existence of large thermo-electromotive forces between rods of some of these earths, made up and treated much as ordinary thermo-junctions, has been established by experiments at high temperatures, and a further investigation of this phenomenon and a study of the resistance of such rods by appropriate methods will form the basis of the main investigations of the department during the coming year. In connection with this, the action of various forms of optical pyrometer is being investigated.

(4) A re-determination of the effect of pressure on the boiling point of sulphur.

Metrological Division.

The work proposed for next year consists partly of maintenance of standards and partly of setting up and standardizing new apparatus.

With regard to the maintenance of standards the following items may be mentioned :—

(1) An intercomparison of the set of end gauges with the 12-inch end gauge, measurements of which have just been carried out by the Board of Trade in terms of their standards.

(2) An intercomparison of the end gauges with the Board of Trade Standard Yard.

(3) Verification of the line yard (No. 2) in terms of the Board of Trade Standard Yard.

(4) Standardization of the complete set of external cylindrical gauges.

(5) Determination of the co-efficients of thermal expansion of yards Nos. 1 and 2.

(6) An investigation into the conditions of permanence of invar and the method of annealing desirable to produce the best result.

(7) The work connected with weights and volumes will be taken over, and an intercomparison of a complete series of weights carried out.

Under the head of new apparatus may be mentioned :—

(1) The 4-metre comparator, which will, it is hoped, be completed in the early part of the year. Four-metre and 10-ft. invar standards will be annealed and afterwards divided and standardized for use with this comparator.

(2) An oven for artificially ageing invar rods is being set up and will shortly be completed. Experiments in this connection will be carried out.

(3) An automatic comparator for end gauges with a set of gauges has, by the courtesy of the French Government, been ordered from the French Ordnance Department, and is to be delivered early in the year.

The Committee hope, in addition, that it may be possible to lay down during the year the base for standardizing long tape measures, for which the demand is considerable.

Metallurgical Division.

Two important researches have been suggested :—

I. *The Influence of Impurities on Copper.*

In making this suggestion the following facts have been recognised :—

(i) The practical difficulties attendant on the production in mass of sound copper containing traces of an individual impurity.

(ii) The work already done in this direction.

(iii) The high degree of purity of present day commercial coppers.

Nevertheless, it has been pointed out to the Committee that—

(*a*) The difficulties of (i) can be surmounted.

(*b*) The bulk of previous work lacks co-ordination, and that much of it has been done on samples too small to possess a practical value.

(*c*) While commercial coppers are of high purity it is, in the present state of knowledge, a difficult matter to forecast from analysis the influence of traces of any given impurity on the working, mechanical, and electrical properties.

This last is the purpose of the proposed research. The impurities examined would be oxygen, sulphur, phosphorus, arsenic, antimony, bismuth, tin, lead, iron, manganese and nickel in amounts varying from 0 to 1 per cent. by steps of 0·1 per cent. The

alloys would be cast in the melting house attached to the department. Outside assistance would be required for rolling. The alloys would be studied in the cast and rolled condition, the tests to include—

(*a*) Working properties.
(*b*) Mechanical properties.
(*c*) Electrical properties.
(*d*) Physical structure.
(*e*) Range of solidification.
(*f*) Corrosion.

It is hoped that this research will be carried out with the assistance of the Alloys Research Committee and some leading Copper firms.

II. *The Relation of Carbon to Iron in Cast Iron.*

The ordinary malleable iron castings of commerce may be divided into two classes:—

(*a*) Those in which, during the annealing process, part of the carbon is removed and the remainder left as amorphous carbon, and

(*b*) Those in which comparatively little of the carbon is removed, practically the whole of it remaining in the amorphous condition.

Class (*a*) is typical of British, Class (*b*) chiefly of American practice. In both the annealing temperatures are very similar, varying from 800° to 850° C., whilst the time required is in both cases similar and fairly long, as a rule taking about 100 hours.

Various observers have shown that if the foregoing temperature of 850° C. is exceeded the annealing time is considerably shortened. Royston, in particular, has indicated that a white cast iron, heated to its melting point, and then cooled either quickly or slowly, rejects a large portion of the carbon from combination. Both Royston and Ledebuhr have shown that pressure at high temperature also favours the precipitation of amorphous carbon.

Other writers have shown the commercial unreliability of a malleable product obtained by simply heating to a high temperature, and on the whole the literature of the subject is extremely conflicting. However, this literature does show that the laws governing the separation of amorphous carbon from carbides of iron are not clearly known.

As illustrating the foregoing, the following experiments may be quoted:—

Experiments on Malleable Cast Iron.

Condition.	Maximum Stress. Tons per square inch.	Remarks.
As cast	15·9	——
Annealed in ore	29·2	Total time in oven = 100 hours.
Heated to 1,030° C. ...	24·0	,, muffle = 4 ,,

In other words, a product having a tensile strength only 5·2 tons per square inch less than that of the annealed metal was obtained in $\frac{1}{25}$th of the time.

Therefore, as the conditions which determine the separation of amorphous carbon at high temperatures are not known, and as the method would prove of some industrial importance, owing to its comparative rapidity, were the conditions known, it seems desirable to thoroughly investigate the matter.

The preliminary stage of the proposed research would consist of an exhaustive examination of the critical ranges of typical white and grey cast irons. This range begins from solidification downwards, and in the first place determinations of the range of solidification of typical cast irons are essential. The region between solidification and 500° C. demands careful exploration, and would involve an examination of the influence of the rate of cooling. Further, cooling curves may possibly be required in which the specimen, whilst cooling, is submitted to considerable pressure.

The conduct of the succeeding stages of the research would be guided by the facts ascertained in the preliminary stage. They will probably include (1) a comparative study of the three or more conditions of carbon in cast irons involving tensile, compression, transverse tests, with chemical and micrographic analyses.

(2) A series of Heat Treatment experiments having for their object the rapid production of temper carbon, in other words, the quick conversion of a hard and brittle metal into a tenacious one.

(3) The influence of varying composition, with especial reference to manganese and silicon.

III. *An Investigation of the so-called Constituents of Quenched Steels, viz.,* "*Austenite,*" "*Martensite,*" "*Troostite,*" *and* "*Sorbite.*"

The inception of this research is due to Professor H. Le Chatelier, of Paris, who is organising it with the Director on an international basis. It is hoped that investigations on the same lines will be made simultaneously in laboratories in America, England, France, Germany, Russia, and Sweden. Attention will be directed in the first instance to determining the conditions of the production of "Austenite," and afterwards to characterising it.

Optical Division.

A.—*Photometry.*

Secondary Standards of Light.—At the request of the Gas Engineers Institute, a comparison of the secondary standards used in various countries, viz., the 10-c.p. Pentane Lamp, the Hefner Alteneck Amyl Acetate Lamp, and the Carcel Lamp, is being undertaken. The Institute have provided the Hefner and Carcel lamps with various accessories, and as similar researches are in progress in France and Germany, the work promises to be of much importance.

Primary Standard.—The Committee feel it is highly desirable to establish, if possible, some primary standard of light, *e.g.*, the radiation from some definite surface at a definite temperature. It is hoped that the high temperature work now in progress in the thermometric department may allow of this being done.

B.—*Optical Tests.*

Photographic Lenses.—The possession of the new bench will enable tests on these to be made more completely and accurately than before.

Telescope and Lens Tests.—Arrangements are in progress, thanks in part to the kindness of Mr. Aitchison, for the more exact examination of small telescopes, especially binocular glasses. The question of the loss of light in these is attracting special attention, while, at the request of a committee of the Optical Society, a scheme is being prepared for the examination of the lenses and other appliances used in opticians' test cases.

OBSERVATORY DEPARTMENT.

The main work in this department, in addition to the ordinary tests, will be the reduction and preparation for the Press of certain of the Antarctic Physical and Magnetic Observations.

Particulars of the testing work are contained in he various test pamphlets, which may be had on application to the Director.

STAFF OF THE LABORATORY.

Director—R. T. Glazebrook, D.Sc., F.R.S.

Observatory Department.

Superintendent—Charles Chree, LL.D., F.R.S.
Chief Assistant—T. W. Baker.
Senior Assistants—E. G. Constable, J. Foster, T. Gunter, W. J. Boxall.
Junior Assistants—E. Boxall, G. Badderly, A. C. Cooper, B. Francis, A. G. Williams.
Boy Clerks—H. A. Maudling, W. J. Stockwell, A. E. Gendle, A. F. Clayden, B. Johnson, W. R. Corrin, Jun.
Caretaker, &c.—W. R. Corrin, Sen., with wife as housekeeper.

Physics Department.

Assistants—J. A. Harker, D.Sc.; A. Campbell, B.A.; H. C. H. Carpenter, M.A., Ph.D.; W. Hugo; C. C. Paterson, A.M.I.C.E.; F. J. Selby, M.A.; F. E. Smith, A.R.C.S.; W. A. Caspari, Ph.D.; H. H. Jeffcott, B.A., B.A.I.
Research Assistant—E. H. Rayner, M.A.
Junior Assistants—S. W. Melsom; S. W. Attwell; P. Longmuir; L. Naylor, B.Sc.
Computer—W. H. Brookes.
Instrument Maker—F. H. Murfitt.
Carpenter—W. Poulter.
Porter—R. Murrison, with wife as housekeeper.
Laboratory Boys—C. H. Unsted, W. H. Eastland, C. Bone, H. Sturgeon, L. E. Harper, W. Drewett.

Engineering Department.

Superintendent—T. E. Stanton, D.Sc., M.I.C.E.
Assistant—C. Jakeman.
Research Assistant—L. Bairstow.
Mechanics—J. Taylerson, C. Hellary, W. Sidding.
Electrician—P. Rivers.
Engineer—H. Tunwell.
Laboratory Boys—W. Poulter, Jun., H. Price, W. Bishop, J. Taylor.

Office.

Clerk and Accountant—G. E. Bailey.
Correspondence Clerk—E. J. Dubensky.
Boy Clerks—A. May, P. H. Durham.

Garden, etc.

S. Hayes, H. Davis.

REPORT OF THE DIRECTOR FOR THE YEAR ENDING DECEMBER 31, 1904.

The more important events of the year are referred to by the Executive Committee. The following Report contains details as to the work in the various divisions.

There have been some changes in the staff. Mr. Attwell joined as a junior assistant in the Metrological Division in April, and in July Mr. Keeling, who had been in charge of that department since its commencement, accepted a post under the Government of Egypt. The Laboratory is much indebted to him for the admirable manner in which he organized the early work of his division, aiming throughout at a high standard of accuracy and workmanship. His place has been taken by H. H. Jeffcott, B.A., T.C.D. By the kindness of Messrs. Sir W. G. Armstrong, Whitworth, & Co., Mr. Jeffcott spent some time in their gauge-room after his appointment, and took up his duties at the Laboratory at the end of the year.

PHYSICS DEPARTMENT.

I. Electricity.

A.—*Fundamental Units.* (*Mr. Smith.*)

(a) *Standards of Resistance.*—An inter-comparison has been made of the mercury standards of resistance constructed last year. The differences found were in agreement (within the limits of the errors of observation) with those previously observed.

The methods of building up resistance coils, having values in ohms approximately equal to some power of 10, have been investigated. The evaluation of a ten-ohms coil, by placing ten-unit coils in series, or by Lord Rayleigh's most convenient "build up" of three 3-ohms coils capable of being placed in series or in parallel, is not sufficiently accurate for standards purposes. Build-up boxes have been designed consisting of coils having resistances in the ratio of the numbers 1.1.2.2.5.10, the arrangement of the coils being such that the lines of flow are of the same form when the separate coils are being evaluated, as when they are placed in series. No contacts form part of the resistance measured, and careful checking proves the build up to be accurate to 0·0001 per cent.

(b) *Standard Cells.*—The investigation of certain anomalies of Clark and cadmium cells has been continued. Special four-limb cells were constructed, designed so as to contain three different samples of any one element of the cell. In this way the instability of the samples was determinable. Mercurous sulphate was the first substance to be investigated, the observations of previous years indicating its behaviour to be most unsatisfactory. The investigation proved the sulphate, as ordinarily prepared, to be quite unsuitable for standard cells, and a standard method of preparation was sought. Three methods proved to be successful. The first of these is a modification of one due to Divers and Shimidzu, the salt being prepared with fuming sulphuric acid and mercury. The second is a precipitation method, while the third is an electrolytic method, due to Prof. H. S. Carhart, Mr. G. A. Hulett, and Dr. F. Wolff. Very satisfactory results were obtained. Six cadmium cells, prepared with samples of mercurous sulphate so made, were taken to the United States by Dr. Glazebrook in September, the object being to compare their E.M.F.'s with those of other cells constructed by Prof. Carhart. Unfortunately, the cells changed in transit; the reason for this is unknown, but will be

investigated. There is little doubt, however, but that a depolariser can now be prepared, such that the E.M.F.'s of cells prepared with samples manufactured at different times will not be different by more than a few hundredths of a millivolt. With purchased samples of mercurous sulphate, cells were prepared having E.M.F.'s different by more than two millivolts.

An investigation has also been made to determine the difference, if any, of E.M.F. between the H form of cell and the tube or Board of Trade form. Since 1892 the H form has been assumed to have a smaller E.M.F. by 0·0004 volts. Cells combining the two forms were constructed, and observations made on both Clark and cadmium cells. The results showed conclusively that no difference so great as four ten-thousandths of a volt exists; the difference, if any, must be very small.

A preliminary report on the anomalies of standard cells was presented to Section A of the British Association at Cambridge.

In the coming year it is hoped that the investigation will be completed, and a satisfactory specification for both Clarke and cadmium cells prepared. The various objections against both kinds of standards when subjected to a fluctuating temperature will also receive attention.

(c) *Ampère Balance of the British Association.*—The construction of the electrical portions of this has been the principal work of the year. The weighing mechanism was completed by Mr. L. Oertling in April, and was tested at Mr. Oertling's works, the results being entirely satisfactory.

The four marble cylinders for use with the balance have been wound and successfully insulated. The turning and screw-cutting of these was performed by Mr. Taylerson, of the Engineering Department of the Laboratory. The two large fixed cylinders have diameters of 13 inches, and are each 11 inches long. The small suspended cylinders are 8 inches in diameter, and approximately 6 inches long. On each fixed cylinder are two double helices of No. 24 bare copper wire. The pitch of each helix is $\frac{1}{18}$ inch, so that the air space between consecutive turns is less than six-thousandths of an inch. Double helices are also wound on the small cylinders. The object of the double helix is to enable the insulation resistance between the strands to be measured. Initially, this insulation resistance was surprisingly low, and great difficulty was at first experienced in raising it to more than a few hundred ohms. Finally, however, an insulation resistance greater than 30,000 megohms was secured for each pair of coils.

To obtain the mean diameter of the coils measurements were made in nine or ten approximately equidistant planes, and fourteen observations made in each plane. A complete survey of the surface of the coils was thus ensured. The measuring apparatus was specially designed, and enabled the diameter of any turn to be determined. Readings could be repeated to one micron. The observed diameters have been plotted so as to illustrate the ellipticity and conicality of the cylinders. The average ellipticity is such that the diameters of the ellipse vary by about 10 micron, while the average difference between the maximum and minimum means of the readings in the various planes is about 12 micron. This latter is a rough measure of the conicality. The dimensions of the coils are probably known with greater accuracy than any coils hitherto constructed.

Many accessories for the balance have also been constructed, and there still remains much delicate fitting to be done. The outlook for a speedy determination of the absolute unit of current is, however, very hopeful.

B. *General Measurements.* (*Mr. Campbell and Mr. Melsom.*)

Tests.—A list of the tests carried out in this Division is given on page 5.

Of special interest may be mentioned the following :—

A number of the leading British instrument makers who were exhibiting at the St. Louis Exhibition had a wide variety of their instruments verified by the Laboratory before sending them to St. Louis. Most of these instruments were intended for measurements of the highest order of accuracy, and the list included many kinds of resistance boxes, several types of potentiometer, insulation and conductivity testing sets, and standard resistances from 0·001 ohm to 1 megohm.

Some small self-inductances of the order of 0·2 to 5 millihenries were measured by Wien's method. In this method a high frequency alternating current is used, and this was furnished by a microphone buzzer giving 700 ∼ per second. Ultimately the buzzer was modified and improved so that an almost pure sine curve alternating current, with a frequency as high as 2,000 ∼ per second, was obtained. An increase of frequency of this amount is of great advantage, as it so increases the sensitiveness of any method used. The small inductances were also compared with larger standard ones already tested (at lower frequencies) against the Standard Air Condensers by Anderson's method; the agreement was satisfactory.

In order to find if any change, due to alternating currents at high voltages, could be detected in a copper conductor, measurements of electrical conductivity were made on samples of Ferranti concentric mains (*a*) which had been in use with high voltages for many years, and (*b*) which had stood idle for the same period. The results showed that no difference due to use could be detected.

Early in the year a set of preliminary experiments were made on a number of samples of guttapercha, and from these were arranged the methods for the actual tests of a large series of samples done later in the year, chiefly by Mr. White and Mr. Rayner. The apparatus used is described below.

The guttapercha samples were in the form of sheets and the coverings on wires (in quarter-mile lengths). For each sample there were two thicknesses of material both for sheets and on the wires. The material was tested for dielectric resistivity at a number of different temperatures, the effects of ageing being found by repeating the tests at intervals extending over six months. Most of these tests were made both with 200 and 1,000 volts, and with one and two minutes' electrification. In addition to the usual direct deflection method, in many cases the loss of charge method was also used. With both the wires and the sheets several series of tests of specific inductive capacity were made, and the effect of varying the temperature was tested. It may be of interest to mention that resistances of the order of 1,000,000 megohms were dealt with by the direct deflection method.

Tests on Laboratory Instruments, &c.—The Standard B.A. Air Condensers were tested, and a higher degree of accuracy than in former determinations was obtained by using a chronograph in conjunction with the standard clock. Some tests of temperature co-efficient were made on several mica condensers.

For the gutta-percha tests a large water tank was set up; the water in this could be maintained within 0°·1 C. by means of an electrical thermometer relay which controlled a number of electric heaters at the bottom of the tank. For the calibration of the galvanometers used in the high resistance tests a subdivided resistance of

100,000 ohms was constructed, capable of bearing easily 1,000 volts. The voltage was measured by an electrostatic voltmeter across a suitable fraction of the resistance. Another resistance of 100,000 ohms was built to act as the standard in the galvanometer circuit.

A set of five non-inductive resistance frames (each 50 ohms and to carry 2 ampères) was constructed. By means of these, comparisons were made, both with direct and alternating current, of one of the Standard Kelvin Electrostatic Voltmeters and one of the Kelvin Balances (to 100 ampères). The agreement was quite satisfactory, and this disproves (for ordinary frequencies) the allegation that when used with alternating currents the accuracy of the Balance is affected by eddy currents in the metal parts near the coils.

Overhead mains were put up connecting the Main Building with the Engineering side in order to bring across current from the Siemens alternator.

For testing resistance boxes, &c., at various temperatures, a large well-lagged cupboard was set up with electrical heating and regulation; uniformity of temperature is ensured by a motor-driven fan which keeps the inside air in vigorous circulation.

Some experiments were made with a view to setting up standard direct-reading moving-coil ammeters and voltmeters free from zero creep. The results of these are encouraging, and a satisfactory solution of the problem seems certain.

For testing current capacities of secondary cells an adjustable resistance for 2 volts (1 to 100 ampères) was constructed.

In connection with low resistance measurements a resistance box of 10,000 ohms, reading to 0·1 ohm, was built.

In Magnetic Testing a number of experiments were made on a modified form of the Isthmus Method with a view to reaching flux densities of 22,000 to 23,000.

For Hysteresis and other magnetic tests a special stand was made by which a primary winding of 30 turns could be applied to a ring in a few minutes. On testing this arrangement the results obtained were in satisfactory agreement with those obtained from the same ring evenly wound in the usual manner.

For Hysteresis tests a Searle Ballistic Wattmeter was set up, and by its help a measurement of hysteresis can be got by observing four throws of the moving coil—a considerably quicker method than the standard one of drawing the hysteresis loop and measuring its area. As this wattmeter must be very sensitive, considerable difficulties arose with it in the earlier part of the work. Three sources of error were traced and almost completely eliminated. These were :—

(*a*) Insufficient inductance in the choking coil used to delay the rise and fall of the magnetizing current.

(*b*) Electrostatic action of the series circuit on the moving coil and damper.

(*c*) Air convection currents caused by the heating of the series coils, which are run at a high current density.

To get over (*a*) a large subdivided choking coil (with closed iron circuit) was built. The electrostatic action (*b*), which was largely due to the necessity of working from a portion of the 100-volt experimental battery, was almost eliminated by applying suitable strips of tinfoil to the surroundings of the moving coil. The convection currents (*c*) were much reduced by placing the series coils further apart and screening the moving coil from them by thick shields of ebonite. For calibrating the wattmeter a simple magnet inductor (a coil slipping over a permanent magnet) was constructed. It is used

as a working standard of magnetic flux, being checked from time to time against a standard mutual inductance. The wattmeter method has been used to test a number of rings, and so far the results have been in good agreement with those given with the same rings by the ordinary ballistic galvanometer method. Some comparison tests were also made on a Ewing Hysteresis Tester.

C.—Electrotechnics. (*Mr. Paterson.*)

Equipment.—Progress has been made during 1904 in the equipment of an electrotechnical department to undertake the testing of electrical apparatus on a commercial scale, and it is hoped that early in 1905 the installation of the necessary apparatus will be complete.

For direct current work cells have been installed with a capacity of 1,000 ampères, and a plug board and resistance has been fitted up for the purpose of regulating this current. There are three Kelvin balances, with capacities up to 600 ampères, connected to a board which enables any one to be put in circuit as required. A water-cooled manganin tube resistance capable of carrying 1,000 ampères and dropping 2 volts, has been constructed at the Laboratory. It has been made specially non-inductive with a view to its employment for alternating currents.

Overhead leads have been brought across from the 300-volt battery in the Physics building, enabling steady currents to be obtained for voltmeter calibrations. The 480-volt supply of the Twickenham Electric Supply Company has also been brought into the room, so that, if necessary, direct current pressures up to 800 volts can be obtained for commercial testing purposes.

For alternating current measurements, three electrometers—voltmeter, wattmeter and ammeter—of the Addenbrooke type, have been bought, together with a switch box for the calibration of the instruments. A Kelvin multicellular voltmeter with a large circular scale at $2\frac{1}{2}$ metres radius, will form the standard for alternating current voltage, all these instruments being so arranged that they can be observed at the same time.

Three step-up transformers giving from 1,000 to 10,000 volts, have been kindly presented by Messrs. Siemens Bros. & Co., who also gave the motor generator installed last year. In addition to these, three step-down transformers have been ordered from the British Electric Transformer Company, giving currents up to 800 ampères.

A low resistance potentiometer has been designed and made at the Laboratory for use in this department.

The following apparatus has been kindly presented to the Laboratory for use in this department:—

Three step-up transformers presented by Messrs. Siemens Bros. & Co.
One galvanometer ,, ,, Crompton & Co.

D.—Special Research. (*Mr. E. H. Rayner.*)

During the past year electrical research work on behalf of the Engineering Standards Committee has been in progress.*

There have been several points on which various sub-committees have required information which could only be satisfactorily given by a series of special experiments.

* Reports embodying the results of this work have been issued by the Engineering Standards Committee.

Among these has been the question of the maximum temperature to be allowed in electrical machinery. This temperature depends on the insulating materials used in their construction, and experiments on the influence of prolonged exposure at various temperatures, both on the electrical and mechanical properties of commercial insulating substances, have been carried out and reported upon. An addition to this report is at present in progress.

A second series of experiments on a similar subject has just been completed, on the temperature distribution in the interior of the field coils of electrical machinery, to obtain some information on the maximum temperature reached, with a view to prescribing a limit at which the insulation, cotton being generally used for this purpose, should be worked.

Experiments on this subject have been made on some ten field coils by different manufacturers, the temperature distribution being obtained by a thermo-electric method by means of a number of thermo-junctions embedded in each coil. Tests have been made at the makers' works, and portable apparatus had to be designed and made for the purpose. The results of this series are now in the printer's hands.

A similar series of experiments on the distribution of temperature in commercial transformers is now commencing, the transformers having been specially wound with the thermo-junctions, sent from the National Physical Laboratory, put in such positions as will best give the information required.

II. Thermometry. (*Dr. Harker and Mr. Hugo.*)

Tests.—During the year tests have been made and certificates granted to the instruments indicated in the list in the Report of the Executive Committee. Of the new tests organised during the year may be mentioned that of the apparatus for testing the flash point of petroleum oils and the electrical test of the Simmance Abady calorimeters for determining the calorific value of gaseous or liquid fuels. Though not belonging strictly to this Department, tests have also been made of the relative radio-activity of a number of minerals and other products.

The process mentioned in the last Report as having been used for verification of the very long thermometers used in certain industries has been found convenient, and the range of substances extended. For instruments of a similar character of very high range and outside the limit of the boiling-point method, a special electrical bath has been constructed.

Tests have also been made on the latest type of Callendar recorder, as a temperature recorder when used with a platinum thermometer, and an elaborate Callendar Griffiths resistance bridge designed for platinum thermometry has been calibrated to the highest accuracy attainable.

Comparisons to a high degree of accuracy of three of the British National Standard Tonnelot thermometers, belonging to the Board of Trade, have been made at a number of temperatures with the Laboratory standards.

New Apparatus Installed.—By the kindness of the Cambridge Scientific Instrument Co., the old Callendar recorder used in the high temperature comparison of standard instruments, mentioned in the last Report, has been exchanged for a fine instrument of the latest pattern, capable of being used either as Wheatstone bridge or potentiometer.

The 240 and 480-volt direct current mains of the Twickenham and Teddington Electric Supply Co. have been brought into the Laboratory, and a specially designed switchboard and convenient regulating resistances, capable of dissipating safely a considerable power, have been installed. Arrangements have also been made by which large currents may be taken from the special thermometric accumulator battery, and the present large regulating resistances have been supplemented by addition of a set of water tubes, capable of easily carrying 500 ampères.

Among the new apparatus made or fitted up in the department may be mentioned:—

5 wire resistance furnaces.

Several carbon tube furnaces.

1 large arc furnace of the Moissan type.

3 new thermometer comparison baths of various forms.

1 bath for temperatures to — 100° C.

Research Work.—(a.) The research on the specific heat of iron at high temperatures, mentioned in the last Report, has been concluded, and will shortly be published. Great difficulties were encountered in elaborating the details of a successful method of preventing the excessive oxidation of the specimen which takes place when it is heated to temperatures over 800° C. and dropped directly into water.

A method has been worked out by which experiments were successfully conducted up to over 1,100° C.

(b.) The chief research in the department has been the commencement of a study of the resistance and thermo-electric properties of solid electrolytic conductors, such as are used in Nernst lamps, with a view to the design of a system of electrical high-temperature measurement based on some of the properties of these materials. Certain apparatus useful in the preparation of the materials in question (zirconia, yttria, &c.) was purchased from the British Nernst Light, Ltd., and to Mr. Solomon, formerly with that Company, we are indebted for much valuable information.

Tubular electric furnaces have been constructed capable of continued use at temperatures well above 2,000° C. By means of these furnaces and a number of thermo-junctions of widely different properties, whose E.M.F. in terms of the standard temperature scale up to 1,300° C. had been previously determined by extended comparisons with the Laboratory standards, a careful determination of the melting-point of platinum was made, using six different junctions for temperature measurement and four different samples of platinum. The results of the different determinations, which were closely concordant, will be published shortly.

The existence, at high temperatures, of large thermo-electric forces between rods of the various earths, made up and treated as ordinary thermo-junctions, has been securely established by direct electrometric methods, and the apparatus necessary for a detailed study of these phenomena is in course of construction.

(c.) *Thermo-junctions.*—A number of comparisons of thermo-junctions of platinum with various platinum alloys of accurately known composition were made with the collaboration of Mr. George Matthey, F.R.S., the results of which are nearly ready for publication, and a considerable number of melting and boiling-points of various substances have been determined for use as fixed points in high-range thermometry.

(d.) *Constants of Steam.*—The results of these experiments are given in the Report of the Engineering Department, as the greater part of the work has been done in that department by Mr. Jakeman.

(e.) *Thermometer Glasses.*—Four specially carefully prepared Kew Standard Thermometers have been studied and calibrated with a view to a comparison between the "Kew Scale" and the hydrogen scale over the ordinary range.

The study of the effect of prolonged annealing and other treatment on various thermometer glasses, mentioned in the last Report, has been continued, and some interesting data obtained as to the progressive movement of the zero-point after various temperature cycles.

The tests on the constancy and general characteristic properties of the different thermometric glasses, supplied by Messrs. Powell & Sons and other makers, have been continued. A number of electrical heating baths have been constructed in order that prolonged annealing may take place at definite temperatures.

Since last year Messrs. Powell & Sons have supplied us with another sample of low temperature glass. This has been studied principally as regards the depression of zero after exposure to temperatures ranging from 13° to 100° C., and the depressions obtained with this sample are less than any yet found with glass made by this firm.

III. Metrology. (*Mr. Keeling and Mr. Attwell.*)

Tests.—During the year tests have been made on "line" and "end" measures of length, co-efficients of expansion, and on various cylindrical screw and other gauges, measuring instruments, &c.

New Apparatus.—A comparator for the calibration of the sub-divisions of line standards of length.

A 4-metre comparator for the measurement of tapes which are intended to be used flat.

An end measuring machine to take work of considerable bulk, and lengths up to 2 metres.

A second H-form steel bar, divided on a platinum iridium strip over 40 inches into $\frac{1}{10}$ths has been acquired.

Messrs. Cammell, Laird & Co. have kindly presented to the Laboratory an H-form invar bar for a 4-metre standard, and this will be divided and standardized next year.

Work Done.—Progress has been made in the construction of a 4-metre water bath comparator, and this, it is hoped, will be completed early next year.

The H-form yards No. 1 and No. 2, and the H-form nickel metre have been standardized, and the values of the sub-divisions (the yards in $\frac{1}{2}$ inches, and the metre in cms.) have been determined to an accuracy of one part in 1,000,000 on the total length.

A set of 27 end measures comprising lengths from 36 inches to 1 inch, have been acquired and standardized. The true length of the 36 inches was found by direct comparison with the steel yard No. 2, and by a process of inter-comparison in the measuring machine, the lengths of all the other end measures were determined in relation to the 36 inches. The values thus obtained agree very favourably with results found by direct comparison with the end standards already belonging to the department.

The master screw of the standard leading screw lathe was calibrated in $\frac{1}{2}$ inches throughout its length, and a compensating bar has been made to correct the errors, the final measurements showing that the screw as compensated was true to within 0·0001 inches over the length of 36 inches.

The co-efficients of expansion of nine nickel bars have been determined, in connection with the investigation undertaken by the metallurgical division.

A commencement has been made on some work undertaken for the Engineering Standards Committee, the object being to determine definite values for various engineering terms.

Five standard sets of tramway rail sections have been deposited at the Laboratory, and during the year many sets of templates have been compared with these. These standards belong to the Engineering Standards Committee, and the tests form one of the various pieces of work undertaken for the Committee.

IV. Chemistry. (*Dr. Carpenter and Dr. Caspari.*)

The main work in the Chemical Department, in addition to the analyses required for the nickel steel, and other metallurgical researches, has been a careful investigation by Dr. Caspari into the chemical components of eleven samples of guttapercha submitted for test. Some interesting results have been obtained, but there is much yet to be done to clear up the chemistry of the guttas.

V. Metallurgy. (*Dr. Carpenter and Mr. Longmuir.*)

Tests.—These include the following investigations, some of which have led to very interesting results:—

(a.) *An Inquiry as to the Possible Causes of Fracture of Four Boiler Plates during Welding under a Steam Hammer.*—It was first shown that strips cut from the fractured plates could be welded without showing any flaws. A thorough microscopic examination of the faulty parts of the welds showed that in all cases these had been primarily caused by an oxidation of the metal surfaces during the welding treatment, for at each place where a crack originated there was an accumulation of oxide of iron among the iron crystals, and it is well known that such oxidation prevents an effective weld from being produced. The investigation, however, showed that one of the plates contained a latent flaw, which was developed into a wide crack under the steam hammer. This flaw could be traced over the whole section under examination. It was quite different in character from a weld in that it was visible to the naked eye, but was barely distinguishable under microscopical magnification at 150 diameters. Where this flaw came under the steam hammer it had widened out to a crack.

(b.) *A Microscopical Examination of a Strip Sheared from a Brittle Butt Strap Plate* showed that up to a maximum distance of about $\frac{1}{8}$ inch from the sheared edge the two structural constituents (ferrite and pearlite) are distorted in such a manner that they are drawn out into threads roughly parallel to one another and to the sheared edge, but that otherwise the distribution of the structural constituents was normal. No cracks, either between or across the ferrite and pearlite areas, were visible.

(c.) *An Investigation as to the Cause of Fracture of an Unused Steel Rail which broke during Unloading on to the Railway Track.*—Chemical and photomicrographic analyses both testified to the uniform character of the fractured rail. The former, however, showed a high phosphorous content, the latter a well-marked parallel arrangement of and sharp junctions between the two main structural constituents. The condition of the rail appeared to be one of general brittleness, attributable to the high phosphorus content and the extreme lamination of the structural constituents.

(d.) *A Microscopical Examination of a Boiler Plate which had Failed under the Hydraulic Test*, while it showed that the structure of the plate in the neighbourhood of the main fracture differed in two respects from that of the body of the plate, viz.,

(1) in the very irregular distribution of the ferrite and pearlite areas,

(2) in the greater clearness with which the ferrite and pearlite areas were defined, did not render it possible to connect causally the structure near the fracture with brittleness. Further, some experiments carried out by us to imitate this particular structure were unsuccessful.

(e.) *The Range of Solidification and the Heating and Cooling Curves of Metals, Alloys, and Slags* have been measured.

(f.) *An Examination of the Structures of Duplicate Samples of Copper Cable, the one Used, the other Unused*, did not point to any ageing action in the used tube. The outer (thin) tubes had a finer structure than the inner (thick) tubes. The type of crystallisation was sharper and more angular in the used than the unused tube; otherwise there appeared to be no difference.

Exhibits of the Photographic Work of the Department were sent by one of us to the St. Louis Exposition, for which a bronze medal was awarded, and to the autumn Exhibition of the Royal Photographic Society.

Research.—Two researches have been completed during the year.

(1) *A very wide Range of Properties of a Series of Nickel, Carbon, Manganese Iron Alloys, prepared by Mr. Hadfield at the Hecla Works, Sheffield, has been carried out.* The originally prepared series contained eight members. At an early stage, however, it was found desirable to prepare two more alloys on account of the abrupt change in the properties between 4 and 8 per cent. nickel. The full series is as follows :—

Laboratory No.	Percentages.		
	Nickel.	Carbon.	Manganese.
39	Nil	0·47	0·95
40	1·20	0·48	0·79
41	2·15	0·44	0·83
42	4·25	0·40	0·82
43	4·95	0·42	1·03
44	6·42	0·52	0·92
45	7·95	0·43	0·79
46	12·22	0·41	0·85
47	15·98	0·45	0·83
48	19·91	0·41	0·96

The tests made on this series may be divided under four heads :—

A.—*Mechanical (in Engineering Laboratory).*

1. Tensile tests—
   (*a*) Yield point.
   (*b*) Ultimate strength.
   (*c*) Extension.
   (*d*) Reduction of area.
2. Young's modulus.
3. Compression tests.
4. Bending tests.
5. Impact tests.
6. Repeated loads tests.
7. Hardness tests.
8. Torsion tests.

B.—*Chemical.*

9. Composition.
10. Corrosion.

C.—*Physical* (*including Metallographical*).

11. Specific gravity.
12. Dilatation.
13. Electrical conductivity.
14. Permeability.
15. Range of solidification.
16. Cooling and heating curves.
17. Photomicrographs in relation to mechanical, heat, and cold treatment.

The tests have in every case been carried out on the forged "normalised" alloys, *i.e.*, on the forged material heated to 800° C. and allowed to cool in a muffle to the ordinary temperature.* The alloys with 6·5 to 16 per cent. nickel were very difficult to machine, and required special preliminary heat treatment.

The results obtained will be, it is hoped, of both practical and theoretical importance. They will be presented shortly to the Alloys Research Committee of the Institution of Mechanical Engineers.

(2) *An Investigation of the Critical Ranges on Heating and Cooling of Modern High-speed Tools* has been carried out with a view to throwing light, if possible, on the changes that occur during heat treatment in works practice. The results have been correlated to structural changes. The tempering of these steels has also been investigated. The results will be submitted to the Carnegie Research Committee of the Iron and Steel Institute by Dr. Carpenter, one of the Carnegie Research Fellows for the year 1904.

VI. Optics.

A.—*Photometry.* (*Mr. Paterson.*)

Test work.—Investigations on the 10 candle-power Harcourt-Pentane lamp, which were begun in the later part of 1903, have been completed during the past year. The following formula, showing the variation in candle-power with humidity and barometic pressure has been found experimentally, and enables the standard to be used in photometric comparisons in which the test lamp is unaffected by atmospheric conditions.

Candle-power $= 10 + 0{\cdot}066\ (10 - \epsilon) - 0{\cdot}008\ (760 - b)$

where ϵ = litres of moisture per cubic meter of pure air.

b = barometic pressure in mm.

Care has to be taken in the setting up and regulation of the lamp as well as in a thorough ventilation of the photometer room, and a standard has yet to be found which combines exact reproducibility with simplicity and ease of manipulation.

Special attention has been paid to the comparison of seven Pentane lamps by different makers against the N.P.L. standard, in order to determine the extent of possible variations in the candle-power of lamps made to the specification of the Metropolitan Gas Referees. The variation in any two lamps has been under 1 per cent., and in most cases the difference is less than $\frac{1}{2}$ per cent., a result which has justified the adoption of this lamp as a standard of illumination.

* In certain cases duplicate tests on the cast material have been made.

A number of standard electric glow lamps—kindly presented to the Laboratory by the Ediswan Company—have been carefully compared against the Pentane lamp, and now form the working standards of candle-power. They have been re-compared from time to time in order to see that no variation has occurred in their illuminating power.

Inter-comparisons have been made by means of glow lamps with the National Standards Bureau, Washington, and the Electrical Testing Laboratories, New York, as well as with the Reichsanstalt. Further investigations to determine the ratios between the standards of candle-power accepted in America, Germany, France, and Great Britain are now being undertaken.

The ordinary photometric test work carried out during 1904 is included in the Table on page 6.

In addition to the tests here mentioned, comparative tests were made on two systems of street lighting to determine the illumination in the street given by gas and electric lamps respectively. For this purpose a portable photometer was constructed, the standard being a previously calibrated electric glow lamp, run off a portable battery of accumulators, the voltage on the lamp being varied and the photometer head remaining fixed. Measurements were made at night on four separate occasions, in streets lighted by the two systems.

Throughout the greater part of the year tests have been in progress on 60 electric glow lamps, to determine whether the overrunning method of testing lamps is any guide to their performance when run under normal conditions. These measurements, which were completed in November, comprise upwards of 5,000 individual candle-power observations. The watts per mean spherical candle-power of each lamp were obtained, after which some were overrun and others subjected to the ordinary life test, a comparison being made between the two methods on the basis of watts consumed per candle at the beginning of the life of each lamp.

Equipment.—In June, the 480-volt supply from Teddington was installed, chiefly for the purpose of generating alternating current for life tests. The motor generator was erected and in working order in July, and an automatic alternating-current voltage regulator, actuated by two relays, was devised for the purpose of keeping the pressure on lamps for life test adjusted to within $\frac{1}{2}$ per cent. This has been working satisfactorily night and day during the remainder of the year. A Berry transformer made by the British Electric Transformer Company supplies current for life tests at any desired voltage.

A list of apparatus presented and bought is appended below. That designed and constructed in the Laboratory includes the following :—

Attachment to photometer bench for measuring candle-power distribution round glow lamps.

Lamp rotator with mercury contacts made for use with photometer bench.

Automatic voltage regulator.

The following apparatus has been kindly presented to the Laboratory for use in this department :—

Flicker photometer presented by Messrs. Alex. Wright & Co.

Lamp rotator presented by The British Thomson-Houston Company.

3 Standard lamps, Fleming-Ediswan pattern, presented by The Ediswan United Electric Light Company.

6 Standard lamps, presented by the Electrical Testing Laboratories, New York.

Apparatus bought includes the following:—

Standard gas meter.
Gas governor.
$2\frac{1}{2}$ kw. adjustable transformer.

B.—*Dioptrical Experiments and Tests.* (*Mr. Selby and Mr. Hugo.*)

This department has recently benefited by the addition to its equipment of a photographic lens-testing bench, constructed by Messrs. R. and J. Beck, and presented to the Laboratory by Mr. J. Stuart, of Messrs. Ross, Ltd., and by Messrs. Beck. Many of the advantages of the apparatus designed by Major Darwin, which has been in use since 1892, are embodied in the new bench, which will enable the measurements to be carried to a higher degree of accuracy than was formerly possible.

An apparatus, designed and presented by Mr. J. Aitchison, for testing the parallelism of the axes of prism binoculars, will also shortly be ready for use, while benches for determining the absorption of light in prism binoculars, and for testing the lenses of oculists' trial cases are under construction.

In addition to the testing of photographic lenses, the work undertaken has included determinations of the optical constants of glass, the accurate measurements of the angles of prisms, and observations on the relative transparency of specimens of glass.

VII. Tide Prediction. (*Mr. Selby and Mr. Brookes.*)

The work of preparing the tide-tables for the Indian ports is proceeding satisfactorily. The tables for 1905 were despatched in September last, while a great part of the work for the 1906 tables is now completed. The predictions for 1907 will be commenced early in February.

The department is prepared to undertake the analysis and reduction of tide-gauge observations.

VIII. Library. (*Mr. Selby.*)

The publications of the following institutions and societies are now received, in addition to those formerly mentioned:—

The Royal Microscopical Society.
The Optical Society.
Société Française de Physique.
Royal Society of South Australia.
Royal Society of Canada.
Laboratoire d'Essais, Paris.
Civil and Mechanical Engineer's Society.
The South African Association for the Advancement of Science.
American Institute of Electrical Engineers.
Imperial Institute.
University of Strassburg.
American Society for Testing Materials.

Koninklijk Nederlandsch Meteorologisch Instituut.

Faraday House.

The Library has also to acknowledge with thanks the receipt of the following periodicals :—

The British Journal of Photography.

The Optical Journal.

The Dioptric Review.

The Revue de Métallurgie has been added to the periodicals purchased for the Library.

The card catalogue has been continued.

REPORT ON THE ENGINEERING DEPARTMENT FOR THE YEAR ENDING DECEMBER 31, 1904, MADE BY THE SUPERINTENDENT TO THE DIRECTOR.

Commercial Testing.—A statement of the nature of the tests which have been made for the public during the year is given in the Report to the Committee.

The testing equipment has been extended during the year by the addition of an impact testing machine, which has been constructed in the workshop. In this machine the notched specimen is supported on a pair of adjustable knife edges carried by the anvil, the blow being delivered by a swinging hammer in the centre of the specimen. Both the anvil and the hammer are suspended by thin steel tapes from overhead shafts and swing in the same vertical plane. The weight of the hammer is 46·7 lbs., and that of the anvil 60 lbs. The anvil and hammer are provided with arrangements for measuring their displacements before and after impact, so that the total absorption of energy in impact can be directly measured.

A tank with the necessary appliances for testing water meters is being fitted up owing to inquiries made for tests of this nature.

A machine for testing guttapercha cord in tension, and autographically recording the load and extension, has been designed and made in the workshop, following to some extent the arrangements adopted at the Silvertown Works.

The number of tensile tests on steel has greatly increased during the year, but the necessity for a larger testing machine is strongly felt, the present 10-ton machine being inadequate for many of the tests demanded.

A vibrating platform for the testing of pressure gauges subject to vibrations of varying periods and amplitude, is being designed in accordance with the arrangements made with the manufacturers of pressure gauges.

The provision of the new lathe for use with high-speed cutting tools, which has recently been procured for the workshop, affords increased facilities for the cutting tests on tools which are now undertaken by the department.

The Standard Leading Screw Lathe.—The house built for the new Whitworth screw-cutting lathe in 1903 and the arrangements for working have been found to be quite satisfactory. The lathe has been fitted with a new compensating bar and a microscope holder for purposes of measurement. One screw for Messrs. Sir W. G. Armstrong, Whitworth & Co. has been cut, and work is now proceeding on three screws which have

been sent from Woolwich Arsenal. Complete sets of tools for cutting these screws have been supplied by the makers of the lathe, but in future these will be prepared in the Laboratory workshop. A complete set for any screw consists of 14 tools, the total number of cuts being 106, exclusive of the cuts necessary for rounding and undercutting the threads. At the fixed rate of cutting, the times of completion of one screw varies from two to three weeks. This could be reduced by adopting a quick return motion for the tool rest, but, from considerations of the extra wear involved, it has not been thought advisable to accelerate the return motion.

Research Work.—1. *The Effect of Wind Pressure on Structures.*—A revolving steel frame for carrying the pressure plates and models of structures has been made and fitted to the 50-foot steel tower erected for the purpose of observations on wind pressure. By this means the pressure surfaces can be kept normal to the wind during the observations. Preliminary experiments have been made on a flat plate 10 feet long by 5 feet broad. The velocity of the wind is measured by a Dines pressure tube placed 5 feet in front of the pressure plate, and which is connected to a tilting gauge on the ground by a pair of lead pipes attached to the framework of the tower. A considerable number of pressure orifices have been made in the pressure plate, any two of which can be connected by similar lead pipes to another tilting gauge at the foot of the tower. By means of simultaneous observations of the two tilting gauges, the velocity of the wind and the pressure at any point of the pressure plate referred to the pressure at its centre can be obtained. It is found that the maximum pressure comes on in gusts of so short a period that a large number of observations are necessary for each orifice in order that a fair average can be obtained. In this way a considerable portion of the plate has been surveyed so that a comparison of the distribution of pressure on plates exposed to the wind and to a uniform current will be obtained. With reference to the resultant pressures on the plate, it was hoped that it would be possible to balance the effect on a large plate against that on a similar small plate, but no definite results have so far been obtained by this method for the case of the two similar plates, 50 square feet and 5 square feet in area respectively, which have been attached to the platform. Preliminary experiments on similar plates of 5 square feet and 1 square foot in area, which were made before the erection of the tower, had led to the conclusion that such a method might be adopted, but apparently it is not suitable for pressure plates of considerable area. Careful observations of the intensities of pressure at corresponding points of the two plates afford the following explanations of the difficulty of balancing the pressure on one plate against that on the other:—

(1) The intensity at corresponding points on the windward sides of the two plates is rarely the same, sometimes the intensity of pressure on one plate preponderating, and sometimes the other, by as much as 25 per cent. of the whole intensity.

(2) The intensities of pressure at corresponding points on the large plate often differ considerably from each other in value, especially in the horizontal direction. This is most likely due to the wind not striking the large plate normally, veering as it does through a considerable angle with great rapidity.

As regards the general results of the observations made up to the present time, it would appear that the distribution of pressure on the windward side of a large plate in the open air is not identical with that over a small plate exposed to a uniform current of air, the intensity of pressure falling off more rapidly from the centre to the sides in the

former case than in the latter. The ratio of the pressures on the windward and leeward sides appear to be practically the same in both cases.

2. *The Resistance of Materials under Alternating Stresses.*—The testing machine for carrying out these experiments has been completed and fitted with a Mather and Platt electric motor, mounted on the same bed-plate, and driving the machine through a modified Oldham coupling. The motor is provided with a speed-regulating arrangement which enables the speed to be varied continuously from 500 to 2,000 revolutions per minute. A detailed description of the machine, and of some preliminary trials to determine the friction constants, was published in *Engineering* on February 17th, 1905. The machine has been used for determining the resistance under alternating stresses of a series of specimens for the research on nickel-steels of the Metallurgical Department.

As the consumption of oil during the tests is considerable, a steam purifier has been fitted up and connected to the experimental boiler, so that all the oil passing through the machine can be cleaned and used again.

For the study of the slip bands and cracks developed in the specimens during the tests, a special dark room has been fitted up in the Engineering Workshop, and equipped with a complete photomicrographical outfit.

Steam Research. (*Mr. Jakeman.*)—The first piece of work undertaken in this research is the determination of the specific heat of superheated steam. The method adopted is the direct measurement of the heat necessary to raise a known weight of steam from and to any temperatures chosen. The steam is heated by an electric current flowing through a coil of wire, and the energy needed is measured by means of an accurate volt and ammeter. A temporary apparatus was constructed in order to test the method and obtain some approximate values for the specific heat. This was in the first instance provided with mercury in glass thermometers. These were found to give considerable trouble owing to the continuous changes of zero they underwent, in spite of a very thorough annealing before use. At the beginning of the year it was therefore decided to provide the outfit for measurement of the temperatures with platinum resistance thermometers, before continuing the experiments.

These thermometers are constructed in the usual way with fine wire wound on mica frames, the resistance being about 2·6 ohms at 0° C. The thermometers are enclosed in steel tubes 1 cm. in external diameter and these tubes are placed directly in the steam.

The bridge used for measuring the resistance is of the type used by Prof. Callendar, with some modifications in detail to suit the special circumstances. The slide wire is 50 cm. long and about $\frac{1}{2}$ ohm resistance. The bridge unit is the change of resistance produced by a shift of $\frac{1}{2}$ cm. on the wire (= nearly ·01 ohm). The coils in series with one end of the wire are 350, 50, 50, 50, 50, 50, 50, 50 units respectively. Thus with the first coil only the two fixed points, 0° C. and 100° C., are both on the slide wire, the "fundamental interval" of the thermometers being adjusted to be 100 bridge units. The addition of each coil afterwards causes a shift in the position of the slider of one-half the length of the wire, so that there are always two positions where balance can be obtained. This gives a very convenient check of the accuracy of the bridge. For these experiments two temperatures are always required, that of the inlet steam and that of the outlet. These may differ by a large quantity, and in order to obtain them quickly it was necessary to duplicate some parts of the bridge. This was done by providing two copper bars, one connected to each of the compensating leads

from the thermometers, and to each of which any number of the coils can be connected independently. Two sliders are also provided, one for each thermometer. A six-pole mercury cup switch is provided, making, with one shift, the circuit through either thermometer, the corresponding compensating lead with the coils arranged and the corresponding slider. Thus the coils and sliders are always set for each temperature and either can be read by shifting the switch into one position or the other.

In the same box is placed a thermo-electric key, a series resistance in the galvanometer circuit with a turning head and a battery switch and reverse. The only detached parts of the apparatus beside the thermometers are the galvanometer and battery. The coils are all of manganin wire, so that temperature changes do not affect the reading, and the contacts are made by large mercury cups, so that trouble with contact resistances does not occur. The whole of the apparatus has been made in the Laboratory workshops.

As the thermometers are adjusted to the bridge unit the readings are direct in platinum degrees, conversion to centigrade degrees being made afterwards by means of tables. The bridge has proved very handy in use, and with a sensitive galvanometer of quick swing, it is possible to take an observation of each temperature within 10 seconds.

During the preliminary tests it was found absolutely necessary to have perfect control over the heating current. To obtain this a large resistance frame has been constructed in the Laboratory workshops. The main frame contains 29 coils regulating the current from 5 to 20 ampères and controlled by a 30-point turning head. A second turning head with 30 points is provided, one turn of which corresponds to the shift of one step on the first head. Thus nearly 900 steps are obtained between 5 and 20 ampères. The heads are of special design to prevent any alteration in contact resistance affecting the adjustment.

By means of this resistance the watts in the circuits are kept constant during any experiment, to a fixed reading on a 3,000-watt wattmeter obtained from Messrs. Elliot & Co.

During the year improvements have been made in the insulation of the heating coil from the case. The superheater is now lined with a glass tube, and the leads have been enclosed in glass tubes, a satisfactory steam joint having been devised.

The work in connection with the research during the year may be briefly summarised as follows :—

1. Manufacture and adjustment of platinum resistance thermometers.
2. Manufacture and adjustment of direct reading bridge for use with above.
3. Construction of large resistance frame with two turning heads for accurate adjustment of current.
4. Provision of two-way switch so that the apparatus may be connected to the Physical Laboratory battery A, when the current is not steady enough in the mains.
5. Calibration of wattmeter used for adjustment of the current.
6. Calibration of large Weston millivoltmeter for measuring the current and potential drop in the heating coil.
7. Lining the superheater with glass to prevent leakage of current and protection of leads with glass for the same purpose.
8. Proof of the dryness of the steam supplied by the boiler by means of the salt test.

While a considerable number of results have been obtained there are difficulties yet to be overcome before these can be considered as completely satisfactory.

Work done by the Workshop Staff.—In addition to the construction of the appliances for the wind pressure and alternating stress researches already alluded to, the staff of the workshop have been engaged in the following work :—

The construction and winding of the marble cylinders for the ampère balance.

The preparation of the test specimens required for the nickel steel research.

The fitting up of the motor, countershafting and striking gear in the new lathe house.

The construction of the impact testing machine.

The construction of the guttapercha testing machine.

Repair and upkeep of the Laboratory plant.

Lighting and Heating Department.—Owing to the accumulation of the deposit from the positives of the main battery, the cells were disconnected, cleaned, and recharged in February. The three experimental batteries have continued in good working order throughout the year. The heating and ventilating arrangements for the new lathe house have proved quite satisfactory. Owing to the demand for electrical energy for the purposes of constant temperature work in the various departments the capacity of the lighting battery has been severely tested during the year.

T. E. STANTON,

Superintendent of the Engineering Department.

REPORT ON THE OBSERVATORY DEPARTMENT FOR THE YEAR ENDING DECEMBER 31, 1904, MADE BY THE SUPERINTENDENT TO THE DIRECTOR.

The work at the Kew Observatory in the Old Deer Park at Richmond, now forming the Observatory Department of the National Physical Laboratory, has been continued during the year 1904 as in the past.

This work may be considered under the following heads:—

I. Magnetic observations.
II. Meteorological observations.
III. Seismological observations.
IV. Experiments and Researches in connection with any of the departments.
V. Verification of instruments.
VI. Rating of Watches and Chronometers.
VII. Miscellaneous.

I. Magnetic Observations.

The magnetographs have been in constant operation throughout the year, and the usual scale value determinations were made in January.

The ordinates of the various photographic curves representing Declination Horizontal Force, and Vertical Force were then found to be as follows:—

Declinometer: 1 cm. = 0° 8′·7.

Bifilar, January, 1904, for 1 cm. δH = 0·00050 C.G.S. unit.
Balance, January, 1904, for 1 cm. δV = 0·00050 C.G.S. unit.

In the case of the Horizontal Force instrument it was found necessary to slightly re-adjust the position of the magnet on June 22.

The curves during the past year have been free from any very large fluctuations.

The principal movements that were recorded took place on the following days:—

January 9–10, 28; February 4–7; April 1–2, 18–19; May 12–14, 28; June 15–16; July 6; August 3; September 25; October 7–8, 21; and November 4–5.

The hourly means and diurnal inequalities of the Declination and Horizontal Force for 1904 for the quiet days selected by the Astronomer Royal have been tabulated as usual, and the results will be found in Appendix I*, together with the monthly means of the Inclination as derived from the absolute observations. Owing, however, to the disturbance of the vertical force produced by electric trams, it has been found impossible to tabulate the curves for this element satisfactorily. This has led to the omission of the tables of diurnal inequalities of vertical force and inclination published previous to 1902.

A correction has been applied to the horizontal force curves for the diurnal variation of temperature, use being made of the records from a Richard thermograph as well as of the eye observations of a thermometer.

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* The Appendices to this Report will appear in the full Report of the work of the Observatory Department, to be issued later. This can be had on application to the Superintendent.

The mean values at the noons preceding and succeeding the selected quiet days are also given, but these of course are not employed in calculating the daily means or inequalities.

The following are the mean results for the entire year :—

From curves	Mean Westerly Declination.....	16° W.
	Mean Horizontal Force	0·18 C.G.S. unit.
From absolute observations, corrected	Mean Inclination	67° N.
	Mean Vertical Force	0·43 C.G.S. unit.

The absolute observations have been reduced to the mean value for the day by applying corrections based on the diurnal variation observed in previous years.

Observations of absolute declination, horizontal intensity, and inclination have been made weekly as a rule.

A table of recent values of the magnetic elements at the Observatories whose publications are received at Kew will be found in Appendix Ia to the present Report.

On February 4, owing to a combined flood and high tide, the river overflowed a considerable part of the Old Deer Park, and the water covered the floor of the magnetograph room to the depth of 6 inches. No serious damage was done, but some photographic trace was lost owing to a short stoppage of the clock and to water getting into the gas pipes.

Early in the year the Vertical Force Magnetograph was taken outside to the Experimental House, and experiments were made with a view to reducing the temperature co-efficient. The alterations made were successful so far as the temperature co-efficient was concerned, but they introduced defects of another character which have not been fully overcome.

In response to requests from several sources, photographic copies have been made of a considerable number of disturbed magnetic curves. Similar copies have heen received from various observatories, including Toronto, Potsdam, Wilhelmshaven, Zikawei, and O'Gyalla.

Considerable progress has been made in measuring and tabulating old Kew declination curves, the expense being defrayed from a grant made by the Government Grant Committee to the Superintendent.

A course of magnetic instruction has been given to Commander Creagh-Osborne, R.N., at the request of the Hydrographer, and to Lieut. A. P. Robinson, R.I.M., at the request of the Under Secretary for India.

On the application of the Argentine Embassy, facilities for taking observations with his magnetometer were afforded to Lieut. E. G. Plate on August 16 and 18.

On the return of the British Antarctic Expedition the magnetic instruments employed in the Expedition were brought to Kew and observations were made by Lieut. Armitage and Mr. L. Bernacchi, the Antarctic observers. During December Mr. Bernacchi has been engaged in the tabulation of the magnetic curves obtained in Victoria Land.

The tabulation of the hourly values of the magnetic curves obtained at Kew during the term days of the International Antarctic programme has been completed.

At the request of the Royal Cornwall Polytechnic Society the Falmouth Vertical Force curves for the selected "quiet" days during 1903 were measured and tabulated, this being the first year when this has been done. The diurnal inequalities deduced for Vertical Force and Inclination appear satisfactory, so far as can be judged by comparison with corresponding results for Kew in years prior to the existence of electric tramways.

Meteorological Observations.

The several self-recording instruments for the continuous registration of Atmospheric Pressure, Temperature of Air and Wet-bulb, Wind (direction, pressure and velocity), Bright Sunshine, and Rain have been maintained in regular operation throughout the year, and the standard eye observations for the control of the automatic records have been duly registered.

The tabulations of the meteorological traces have been regularly made, and these, as well as copies of the eye observations, with notes of weather, cloud, and sunshine, have been transmitted, as usual, to the Meteorological Office.

With the sanction of the Meteorological Council, data have been supplied to the Council of the Royal Meteorological Society, the Institute of Mining Engineers, and the editor of "Symons' Monthly Meteorological Magazine." On the initiative of the Meteorological Office, special cloud observations have been made with the Fineman nephoscope in connection with the International scheme of balloon ascents.

Bright Sunshine.—As explained in the Annual Report for 1901, Table III, Appendix II*, in the present Report, gives the monthly and annual percentages according to both the "old" and the "new" points of view. This year, as in 1901 to 1903, the new method gives for the annual mean percentage a value greater than that given by the old, in the proportion roughly of 11 to 10, mainly due to the fact that the new method allows less weight than the old to the winter months.

Earth Thermometers.—The two Symons' earth-thermometers on the lawn, one at a depth of 1 foot and the other at a depth of 4 feet, have been read at 10 a.m., 4 p.m., and 10 p.m. daily throughout the year, and the 10 a.m. readings have been forwarded weekly to the Meteorological Office, together with the corresponding readings of the Solar Radiation and Terrestrial Radiation thermometers.

Electrograph.—This instrument worked generally in a satisfactory manner during the year.

New "leads" from the chloride of silver battery to the Electrometer were fitted in May, and the battery was overhauled, re-charged, &c., in July, but there has been no serious stoppage.

The portable Electrometer, "White No. 53," which is regularly used for taking eye observations at the fixed station on the observatory lawn, was compared with a battery of standard Clark cells in July and December, and its scale value was found to have remained constant.

Determinations of the scale value of the Electrograph were made on January 15, May 12, July 7 and 11, and September 27.

A series of curves—ten a month—have been selected as representative of the variations of potential on electrically "quiet" days, defined as days when irregular fluctuations of potential are fewer than usual. These curves have been tabulated and the results appear, with the permission of the Meteorological Office, in Appendix II*, Tables IV and V. Owing presumably in large measure to the fewness of the selected days, the values deduced from the actual curve measurements show in some months a considerable non-cyclic element. This element has been eliminated from the diurnal inequality in the way customary in dealing with meteorological data.

Similar curves have also been selected and tabulated on corresponding lines for the years 1899, 1900, and 1901, and there are now six years' tabulations and results available for discussion, which it is hoped may be proceeded with during 1905.

* *See* footnote, p. 38.

Inspections.—In compliance with the request of the Meteorological Council, the following Observatories and Anemograph Stations have been visited and inspected:—Aberdeen, Deerness (Orkney), Glasgow, Fort William, and Yarmouth, by Mr. Baker; and Radcliffe Observatory (Oxford), Stonyhurst, Fleetwood, Manchester, Armagh, Dublin, Valencia, and Falmouth, by Mr. Constable.

At the request of the Meteorological Council, immediately after Christmas, Mr. Baker went to Fort William and dismounted the instruments belonging to the Meteorological Office, which are now stored at Kew.

III. Seismological Observations.

Professor Milne's "unfelt tremor" pattern of seismograph has been maintained in regular operation throughout the year; particulars of the time of occurrence and the amplitude in millimetres of the largest movements are given in Table I, Appendix III.

The largest disturbance recorded during the year took place on April 4, when the maximum amplitude exceeded 17 mm.

A detailed list of the movements recorded from January 1 to December 31, 1904, has been made and sent to Professor Milne, and will be found in the 'Report' of the British Association for 1904, "Seismological Investigations Committee's Report."

IV. Experimental Work.

Fog and Mist.—The observations of a series of distant objects, referred to in previous Reports, have been continued. A note is taken of the most distant of the selected objects which is visible at each observation hour.

Atmospheric Electricity.—The comparisons of the potential, at the point where the jet from the water-dropper breaks up, and at a fixed station on the Observatory lawn, referred to in previous Reports, have been continued, and the observations have been taken every day when possible, excluding Sundays and wet days. The ratios of the "curve" and the "fixed station" readings have been computed for each observation, and these throw considerable light upon the action of the self-recording electrometer, especially with reference to the insulation problem.

Earth Thermometers.—A number of observations were made with the Symons' pattern earth thermometers in the lawn, and others of similar type, with a view to ascertaining how the readings are likely to be affected under normal conditions by the changes of temperature to which these instruments are exposed during the time required to haul them up and read them.

Recording Meteorological Instruments.—Observations have been taken and experiments made with various self-recording instruments of new types by Messrs. Lander & Smith, of Canterbury, including a sun-shine recorder, an anemograph, a thermograph, and a rain gauge.

A Dines-Baxendell non-oscillating maximum pressure plate by Mr. Halliwell, of Southport was erected on the roof and its behaviour observed; its scale value was checked by direct experiment with weights.

Effects of Pressure on Watch Rates.—At the suggestion of Mr. T. D. Wright, experiments have been made as to the effects of reduced pressure on the rates of watches of various types. These experiments are still in progress. The watches employed were lent by Mr. Bonniksen, Messrs. Nicole, Nielsen & Co., Messrs. Usher & Cole, and Messrs. Wright & Craighead.

Magnetometer Magnets.—A number of experiments were made on the "pole-distance" and other properties of Collimator and "mirror" magnets, and the results were discussed in a paper* read before the Physical Society in May.

V. Verification of Instruments, exclusive of Watches and Chronometers.

The subjoined is a list of the instruments—exclusive of watches and chronometers—examined in the year 1904, compared with a corresponding return for 1903 :—

	Number tested in the year ending December 31.	
	1903.	1904.
Air-meters	24	9
Anemometers	14	6
Aneroids	86	170
Artificial horizons	21	27
Barometers, Marine	103	116
,, Standard	112	108
,, Station	83	43
Binoculars	1,048	1,027
Compasses	9	29
Hydrometers	353	706
Inclinometers	8	9
Levels	16	5
Magnetographs	—	1
Magnets	15	5
Milk-test apparatus	89	202
Rain Gauges	67	12
Rain-measuring Glasses	131	32
Sextants	901	957
Sunshine Recorders	6	—
Telescopes	3,180	2,943
Theodolites	23	13
Thermometers, Clinical	19,393	15,903
,, Deep sea	56	41
,, High Range	42	42
,, Hypsometric	45	15
,, Low Range	51	53
,, Meteorological	2,851	3,157
,, Solar radiation	67	71
,, Standard	127	75
,, Other Forms	1	2
Unifilars	5	4
Miscellaneous	35	14
Total	28,962	25,797

Duplicate copies of corrections have been supplied in 43 cases.

* *Phil. Mag.*, August, 1904, pp. 113–145.

The number of instruments rejected in 1903 and 1904 on account of excessive error, or for other reasons, was as follows :—

	1903.	1904.
Thermometers, clinical	79	83
„ ordinary meteorological	80	98
Sextants	102	127
Telescopes	172	145
Binoculars	11	10
Various	79	128

There were at the end of the year in the Observatory, undergoing verification, 8 Barometers, 21 Aneroids, 668 Thermometers, 2 Hydrometers, 18 Sextants, 322 Telescopes, 41 Binoculars, 3 Unifilar Magnetometers, 1 Inclinometer, 17 various.

VI. Rating of Watches and Chronometers.

The number of watches sent for trial this year is 429, as compared with 458 in 1903.

The "especially good" class A certificate was obtained by 151 movements. The high degree of excellence to which attention was called in last year's Report has been fully maintained, and there have been some exceptionally fine performances.

The following figures show the percentage number of watches obtaining the distinction "especially good," as compared to the total number obtaining class A certificates :—

Year	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.
Percentage "especially good"	16·6	30·5	28·0	22·1	26·6	35·4	35·5	31·6	42·4	50·2

The 429 watches received were entered for trial as below :—

For class A, 378; class B, 24; and for the subsidiary trial, 27. Of these, 301 were awarded class A certificates, 21 obtained class B certificates, 24 passed the subsidiary test, and 83 failed from various causes to gain any certificate.

In Appendix IV* will be found a table giving the results of trial of the 51 watches which gained the highest number of marks during the year. The first place was taken by the keyless fusee tourbillon-lever, minute and split seconds chronograph watch, No. 2,547, fitted with an "Invar" balance, and sent by H. Golay, London. This watch obtained 93·2 marks, which is the highest number yet obtained by an English lever watch.

It was very closely followed by the Bar-lever watch, No. 116,477, sent by Patek Philippe et Cie, of Geneva, which was awarded 93·0 marks.

There has been a marked increase in the number of movements obtaining over 90 marks, the total this year being 12. The lowest number of marks in the list of the first 51 performances this year is as high as 85·6.

The percentage of "especially good" certificates has again decidedly increased.

Marine Chronometers.—During the year, 41 chronometers were entered for the Kew A trials and 2 for the B trials; of these, 34 gained A certificates, 2 gained B certificates, and 7 failed.

Miscellaneous.—Two "speed-of-flight" chronograph watches have been tested for Messrs. Armstrong, Whitworth, & Co.

Two photometer-clocks, to be used in the testing of the illuminating power of coal-gas, have been examined.

* *See* footnote, p. 38.

A mean-time regulator, by Usher & Cole, London (intended for use in the Transvaal), has been rated for the Meteorological Office.

A four-legged gravity escapement centre-seconds clock was tested at various temperatures, but failed to pass.

The standard clock, Morrison 8702, presented by Lady Galton, was set up at Bushy House in February, and has been running regularly since that date. It is kept at a reduced pressure of about 28 inches of mercury, and the "leakage" of air and the variation of daily clock rate are but small.

VII. Miscellaneous.

Commissions.—The following instruments have been procured, examined, and forwarded to the Institutions on whose behalf they were purchased:—

For India.—10 granitine photographic dishes.

For Mauritius.—1 Sprengel mercury pump, set of spare tubes, and McLeod gauge; 1 standard barometer, Newman pattern; 6 tubes with mercury for Fortin standard barometers, and 6 for marine barometers.

For Toronto.—10 granitine photographic dishes and 2 ivory scales.

Paper.—Prepared photographic paper has been supplied to the Observatories at Hong Kong, Mauritius, St. Petersburg, Toronto, and Oxford (Radcliffe); and through the Meteorological Office to Aberdeen, Fort William, and Valencia.

Photographic paper has also been sent in quarterly instalments to the India Office for use at Colaba (Bombay), Calcutta, Madras, and Kodaikanal.

Anemograph and Sunshine Sheets have been sent to Hong Kong and Mauritius; and Seismograph rolls to Mauritius.

Pendulum Observations.—The pendulums employed in the British Antarctic Expedition have been swung by Mr. Constable to furnish data for comparison with those obtained before the Expedition set out. The observations are still incomplete.

Telescopes.—A considerable number of observations have been made in connection with the testing of various new forms of telescopes for the Admiralty.

Falmouth Magnetic Observations.—The Declination and Horizontal Force results obtained at Falmouth on the "quiet" days selected by the Astronomer Royal during the twelve years 1891 to 1902, have been discussed, and a paper dealing with the results has been communicated to the Royal Society.

Visit of the Council of the Royal Meteorological Society.—Captain Wilson Barker, the President, and other Members of the Council of the Royal Meteorological Society, with their friends, were shown over the Observatory on the afternoon of June 8.

Painting.—During the summer the whole outside of the main building was painted by H.M. Office of Works.

Library.—During the year the Library has received publications from:—

17 Scientific Societies and Institutions of Great Britain and Ireland,
105 Foreign and Colonial Scientific Establishments,

as well as from several private individuals.

The card catalogue has been proceeded with.

CHARLES CHREE,
Superintendent.

List of Instruments, Apparatus, &c., the Property of the National Physical Laboratory Committee, at the present date out of the custody of the Director, on Loan.

To whom lent.	Articles.	Date of loan.
The Science and Art Department, South Kensington.	Articles specified in the list in the Annual Report for 1893	1876
Professor W. Grylls Adams, F.R.S.	Unifilar Magnetometer, by Jones, No. 101, complete	1883
	Pair 9-inch Dip Needles with Bar Magnets	1887
Lord Rayleigh, F.R.S.	Standard Barometer (Adie, No. 655)	1885
New Zealand Government.	Unifilar Magnetometer, by Jones, marked N.A.B.C., complete	1899
	Dip Circle, by Barrow, with one pair of Needles and Bar Magnets	1899
	Tripod Stand	1899
Scottish Antarctic Expedition.	Dip Circle, by Barrow, No. 24, with two pairs of Needles, Bar Magnets, and a Tripod Stand	1902

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